IMAGE Sample Textbook Page in Undergraduate-level Astronomy

9.0 Earth's Magnetism

An ordinary compass works because the Earth is itself a giant magnet with a north and a south pole. Navigators have known about the pole-seeking ability of magnetized compass needles and lodestone for thousands of years. During the last two centuries, much more has been learned about the geomagnetic field and how it shapes the environment of the Earth in space.

The geomagnetic field is believed to be generated by a **magnetic dynamo** process near the core of the Earth through the action of currents in its outer liquid region. Geologic evidence shows that it reverses its polarity every 250,000 to 500,000 years. In fact, the geomagnetic field is decreasing in strength by 5% per century, suggesting that in a few thousand years it may temporarily vanish as the next field reversal begins. Although the geomagnetic field deflects high-energy cosmic rays, past magnetic reversals have not caused obvious biological impacts traceable in the fossil record. Earth's atmosphere, by itself, is very effective in shielding the surface from cosmic rays able to do biological damage. The location of the magnetic poles at the surface also wanders over time at about 10 kilometers per year. Mapmakers periodically update their maps to accommodate this drift.

The domain of space controlled by Earth's magnetic field is called the **magnetosphere.** The geomagnetic field resembles the field of a bar magnet; however, there are important differences due to its interaction with the **solar wind:** an interplanetary flow of plasma from the Sun. The magnetosphere is shaped like a comet with Earth at its head. The field on the day side is compressed inwards by the pressure of the solar wind. A boundary called the **magnetopause** forms about 60,000 kilometers from Earth as the solar wind and geomagnetic field reach an approximate pressure balance. The field on the nightside of Earth is stretched into a long **geomagnetic tail** extending millions of kilometers from Earth. Above the polar regions, magnetic field lines from Earth can connect with field lines from the solar wind forming a **magnetospheric cusp** where plasma and energy from the solar wind may enter. Ionized gases from Earth's upper atmosphere can escape into the magnetosphere through the cusp in gas outflows called **polar fountains.** The magnetosphere is a complex system of circulating currents and changing magnetic often affected by distant events on the Sun called "space weather." The conveyor belt for the worst of these influences is the ever-changing solar wind itself. Space weather "storms" can trigger changes in the magnetospheric environment, cause spectacular aurora in the polar regions, and lead to satellite damage and even electrical power outages.

9.1 Trapped Particles and Other Plasmas

Within the magnetosphere there are several distinct populations of neutral particles and plasmas. The **Van Allen Radiation Belts** were discovered in 1958 during the early days of the Space Age. The inner belts extend from an altitude of 700 up to 15,000 km and contain very high-energy protons trapped in the geomagnetic field. The outer belt extends 15,000 to 30,000 km and mostly consists of high-energy electrons. Geosynchronous satellites orbit Earth just outside the outer belt. Human space activity is confined to the zone within the inner edge of the inner belt. Space-suited astronauts exposed to the energetic particles in the Van Allen Belts would receive potentially lethal doses of radiation. The particles that make up the Van Allen Belts bounce along the north- and south-directed magnetic field lines to which they are trapped like water flowing in a pipe. At the same time, there is a slow drift of these particles to the west if they are positively charged, or east if they are negatively charged. There are also three additional systems of particles that share much the same space as the Van Allen Belts, but have much lower energies: the geocorona, the plasmasphere, and the ring current.

Extending thousands of kilometers above Earth is the continuation of its tenuous outer atmosphere called the **geocorona.** It is a comparatively cold, uncharged gas of hydrogen and helium atoms whose particles carry little energy. In the geocoronal region, there is a low-energy population of charged particles called the **plasmasphere,** which is a high-altitude extension of the ionosphere. Unlike the geocorona, the plasmasphere is a complex, ever-changing system controlled by electrical currents within the magnetosphere. These changes can cause this region to fill up with particles and empty over the course of hours or days.

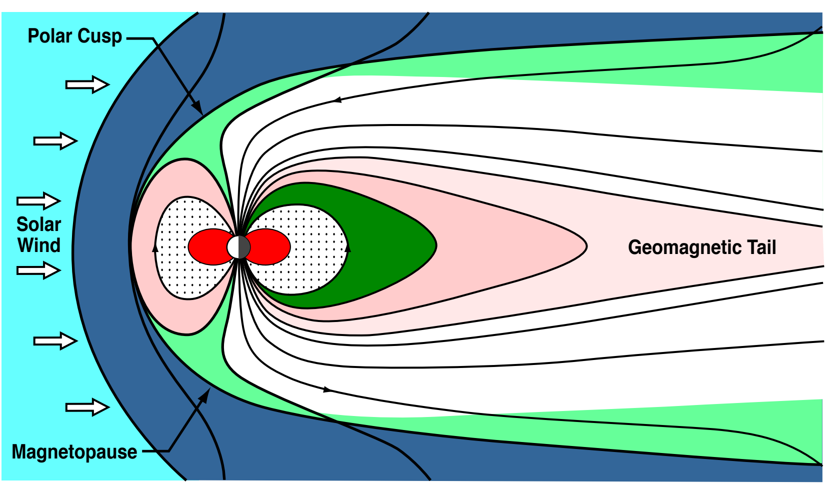

Figure 5-1 Earth's Magnetic Field.
The geomagnetic field resembles the field of an ordinary bar magnet. The north magnetic pole of Earth is located near the south geographic pole, while the south magnetic pole of Earth is located near the north geographic pole. The figure also shows the major regions of Earth's magnetosphere. The filled region shown in red is called the plasmasphere. The dotted region contains the Van Allen Radiation Belts and the ring current. The region shown in green just outside of the ring current zone contains the plasmasheath.